TITLE

5 METHOD, SYSTEM, AND NETWORK ENTITY, FOR ADAPTIVE RESERVATION
OF CHANNELIZATION CODES
AND POWER

10 **FIELD AND BACKGROUND OF THE INVENTION**

The invention generally relates to adaptive reservation of
channelization codes and/or power for downlink, preferably
for the DSCH (downlink shared channel) and/or the HS-DSCH
15 (high speed downlink shared channel) which is part of the
HSDPA (High Speed Downlink Packet Access) concept.

The downlink shared channel (DSCH) in UTRAN (Universal
Terrestrial RAN (Radio Access Network)) is a packet channel
20 which is time shared by multiple users. The DSCH may be
mapped to one or multiple PDSCHs (Physical Downlink Shared
Channels) having a spreading factor between 4 and 256. The
DSCH offers high data-rates and fast scheduling with bit rate
modification every 10 ms, which makes it attractive for
25 bursty packet applications such as web browsing, etc. The HS-
DSCH can be regarded as an enhanced DSCH which offers bit
rate modification every 2 ms as well as adaptive modulation
and coding. The HS-DSCH is mapped to HS-PDSCH (high speed
physical downlink shared channel).

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In order to facilitate fast bit rate modification, a certain
set of channelization codes is usually reserved for each DSCH
as illustrated in Figure 1. This means that time delays due

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to release and setup of new codes can be avoided. However, this is done at the expense of potentially wasting part of the limited code resources when the PDSCH is using the higher spreading factors. It were therefore of advantage when the reserved codes are adjusted adaptively according to traffic load in the cell, among others.

Link Adaption (LA) techniques are commonly used for control (i.e. bit rate selection) of the DSCH. LA aims at minimizing the transmit power variations of the PDSCHs by transmitting with lower bit rates to UEs (User Equipments) which are far from the BS (Base Station) compared to those close to the BS. The selected bit rate for each UE can be expressed as a function of the power allowed for the PDSCH and the associated DPCH ($P_{txPDSCHallowed}$ & P_{txDPCH}), the planned EbNo's for the channels (ρ_{PDSCH} & ρ_{DPCH}), and the bit rate of the associated DPCH (R_{DCH}) (DPCH = Dedicated Physical Channel). According to the LA criteria, the bit rate to be allocated a user is therefore expressed as

$$R_{DSCH,LA} = Round\left\{\frac{P_{txPDSCHallowed}\,\rho_{DPCH}}{P_{txDPCH}\,\rho_{PDSCH}}R_{DCH}\right\} \qquad (1)$$

where *Round{}* denotes truncation to the nearest possible bit rate. That can e.g. be 32 kbps, 64 kbps, etc., depending on the reserved channelization codes. Knowledge of P_{txDPCH} is obtained through average measurements.

Provided that there are sufficient data to be transmitted on the PDSCH, the LA algorithm will automatically result in the following property:

$$E\{P_{txPDSCH}\} \cong P_{txPDSCHallowed} , \qquad (2)$$

where the mathematical operator $E\{\}$ takes the expectation over time. If the relation in equation (2) is false, then it indicates that the DSCH is being poorly exploited. Various reasons for this could be that too much power has been

5   reserved for the PDSCH under the given traffic load or that channelization code blocking is occurring, where the intended LA bit rates according to equation (1) are limited by the minimum allowed spreading factor, i.e. $R_{DSCH} < R_{DSCH,LA}$. Even though equation (2) is valid, there might still be room for

10 optimization by allowing a larger fraction of power to be reserved for the PDSCH. Effective utilization of the DSCH by using LA does therefore depend on the settings of $P_{txDSCHallowed}$ and the spreading factor of the root channelization code, SF_{min}.

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SUMMARY OF THE INVENTION

It is an object of the present invention to provide for

20 adaptive setting or reservation of channelization codes and/or power for the downlink, e.g. DSCH and HS-DSCH.

According to the present invention this object is achieved by a method according to any of the independent method claims

25 and/or a system according to any of the independent system claims.

The invention provides a system, method, and network entity, for adaptive reservation of channelization codes and/or

power, preferably for DSCH and HS-DSCH.

According to one aspect, a method, system, and/or network
entity are provided for adaptive setting or reservation of
5   channelization codes and/or power for downlink channel in a
communication network, in particular for DSCH and HS-DSCH,
using parameters ($P_{txDSCHallowed}$, SF_{min}) for minimum allowed
Spreading Factor, SF, and/or allowed power level, the
parameters being set depending on the traffic load, the total
10 cell load and/or the availability of channelization codes.

The adaptive setting or reservation of codes and/or power is
conducted per logical cell. There is no coordination between
setting or reservation of codes and/or power resources from
15 one cell to another.

It is one of the advantages of the invention that the
reserved codes are adjusted adaptively according to traffic
load in the cell, among others.
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The presented algorithm opens for effective utilization of
the DSCH when using link adaptation techniques, as well as
the HS-DSCH. Especially for cases where the BS carriers a
mixture of RT (Real Time) and NRT (Non Real Time) users,
25 which are mapped to different channel types, such as FACH
(Forward Access Channel), DCH (Dedicated Channel), DSCH
(Downlink Shared Channel), and HS-DSCH (High Speed Downlink
Shared Channel). The algorithm optimizes the usage of both
code and power resources. This will in general result in a
30 capacity gain or improved quality in terms of lower queuing
times for NRT user, less blocking/dropping, etc.

As mentioned above, the algorithm provides a gain in terms of

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increased system capacity and/or quality for cells using the
DSCH and/or HS-DSCH.

The presented algorithm opens for effective utilization of
5   the DSCH when using link adaptation techniques as well as the
HS-DSCH. The invention discloses a method for adaptive
adjustment of root spreading factor and DSCH power. The
adaptation is preferably based on three kind of measurements:
1. The average transmitted power P_txDSCHest of the PDSCH,
10   2. The relative activity factor A of the PDSCH,
3. The weighted code blocking rate B.

The invention also presents a territory method for
channelization code allocation. The following definitions of
15   code territories is introduced:
- Dedicated DSCH capacity
- Default DSCH capacity
- Additional DSCH capacity

20   Further features and advantages of the present invention are
defined in the following.

BRIEF DESCRIPTION OF THE DRAWINGS

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Fig. 1 shows a schematic block diagram illustrating
DSCH code allocation policy in an embodiment of the present
invention,

30   Fig. 2 illustrates an example of allocated bit rates
and Tx power for the DSCH in an embodiment of the invention,

Fig. 3 shows another example of allocated bit rates and Tx power for the DSCH in an embodiment of the invention,

Fig. 4 illustrates further examples of the DSCH behaviour before and after adjustment of the reserved Tx power level in an embodiment of the invention,

Fig. 5 shows an illustration of territory regions for DSCH/HS-DSCH code allocation schemes according to embodiments of the invention, and

Fig. 6 shows a schematic block diagram illustrating an embodiment of the present invention.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS
OF THE INVENTION

As mentioned above, effective utilization of the DSCH by using LA depends on the settings of $P_{txDSCHallowed}$ and the spreading factor of the root channelization code, SF_{min}. The present invention provides adaptive algorithms for adjustment of these parameters.

Once it has been decided which spreading factor the root code should have, the next task is to determine which node in the tree to reserve. An algorithm for this part is also disclosed herein. This algorithm is basically based on a dynamic territory partition of the code tree, which is derived to avoid situations where the code tree becomes highly fragmented. Using this approach, a trunking efficient solution is provided for typical scenarios where the code tree is shared between user equipments (UEs) on DCH, DSCH,

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FACH, etc.

The HS-DSCH specified within 3GPP, as part of the HSDPA
concept, also requires adaptive algorithms for reservation of

5   code resources as well as power levels. This is basically due
to the fact that it is assumed within 3GPP, that the HS-DSCH
is operated with constant power, i.e. no power control.

The constant HS-DSCH power level should, however, be

10   periodically adaptively adjusted according to load conditions
in the cell as well as other factors. The algorithm specified
in the present invention is therefore equally applicable to
HS-DSCH. This applies also for cases where the code resources
for the HS-DSCH is changed dynamically in order to facilitate

15   variable bit rates and for cases where varying number of
multi codes are applied.

In the following, the adaptive adjustment of root spreading
factor and DSCH power will be described. The optimum setting

20   of the two parameters ($P_{txDSCHallowed}$ and SF_{min}) depends on the
traffic load as well as the total cell load (measured by
power) and the availability of channelization codes. These
factors are all considered to be time-variant, which leads to
the conclusion that $P_{txDSCHallowed}$ and SF_{min} preferably are

25   adaptively adjusted in order to optimize the overall cell
performance. It is proposed here to base the adaptation on
three kinds of measurements, seen over a certain observation
period. These measurements are:1)   the average transmitted
power of the PDSCH, $P_{txDSCHest}$

30   2)   the relative activity factor A of the PDSCH. The
activity factor A, equals zero if the PDSCH is silent during
the observation and 0.5 if the DSCH is active 50% of the time
with the observation period. Hence, A ranges from 0 to 1. ;

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3)   the weighted code-blocking rate, B. This factor is
defined as the relative time during the observation period,
where a larger bit rate could have been allocated to a UE
according to the LA criteria in equation (1) compared to the
5   actually assigned bit rate when taking the minimum allowed SF
into account. Hence, B ranges from 0 to 1. If $B=0$, then it
indicates that at no time during the observation period did
it occur that the minimum allowed SF was too high.

10   In order to further underline the meaning of these measures,
let us consider two examples.

Fig. 2 shows an example where three different UEs have been
transmitted on the PDSCH during the observation period. UE #3
15   is apparently located close to the BS, since it has the
highest bit rate. UE #1 is far from the BS, since it has been
allocated a relative low bit rate. During the last scheduling
window in the observation period, there are no data available
for transmission on the DSCH. This gap in the transmission is
20   typically too short for dedicated channels to be scheduled
during this period, i.e. some capacity is wasted.

For this particular case, we have $A=0.75$, $B=0$ ($R_{DSCHmax}$ is not
exceeded), and $P_{txDSCHest}=0.75 P_{txDSCHallowed}$.
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Fig. 3 presents another case, where UE #3 actually could have
been allocated a higher bit rate according to the LA criteria
(1), but a lower bit rate was allocated according to the
minimum allowed SF. The lower bit rate for UE #3,
30   automatically results in a lower average Tx power during the
period where UE #3 is receiving data. This is not desirable
according to the LA criteria expressed in (2), i.e. a lower
minimum SF should be reserved (if possible).

For this particular case, we have A=1.0 , B=0,25 (25% of the time a higher bit rate could have been assigned), and $P_{txDSCHest} < P_{txDSCHallowed}$.

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Based on these examples, four simplified criterias are proposed for adjustment of the allowed power level and the minimum allowed SF.

10   If A is smaller than TH_{A1}, and $P_{txDSCHest}$ is smaller than $P_{txPDSCHallowed}$ minus a certain defined or set value (e.g. threshold value) X ($A < TH_{A1}$ and $P_{txDSCHest} < (P_{txPDSCHallowed} - X)$), then decrease the reserved power, preferably by the value X, or a fraction thereof.

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The reason is that when the activity on the DSCH is too low to keep it almost constant busy, one option is to reduce the reserved power level, which automatically will result in smaller assigned bit rates and therefore also longer transmit
20   times, i.e. a higher activity on the channel. This is obvious from equation (1). The threshold parameter TH_A which lies between 0 and 1 and X are strongly related. Assuming that the offered traffic is identical in two consecutive observation periods, it can be shown that setting $TH_A = 10^{(-XdB/10)}$
25   results in fulfilment of equation (2) in the following observation period provided that $A \cong TH_A$ in the previous period.

If A is greater than TH_{A2}, and $P_{txDSCHest}$ is greater than
30    $P_{txPDSCHallowed}$ minus the value X ($A > TH_{A2}$ and $P_{txDSCHest} > P_{txPDSCHallowed} - X$), then increase the allowed power, preferably by X.

The reason for this is that only when there is constant high activity on the DSCH (e.g. $TH_{A2}=0.9$) and the power level is close to or higher than the reserved value, it makes sense to increase the reserved power level. If the activity factor is lower than unity, it implicitly indicates that there are no packets in the queue, i.e. no need for increased power (capacity). However, before we increase the reserved power level, we must of course consider the total power level in the cell in order to avoid saturation or clipping in the downlink power amplifier (PA).

If B is greater than TH_B, and A is greater than TH_{A2} ($B>TH_B$ and $A>TH_{A2}$), then decrease SF_{min} (allowing higher bit rates): The reason herefore is that if it happens more than a certain fraction of the observation period ($TH_B \in [0;1]$), that higher bit rates than $R_{DSCHmax}$ are requested according to the LA criteria in equation (1) and the DSCH is constantly busy, then one should try to increase $R_{DSCHmax}$, i.e. decrease SF_{min} with a factor of two. However, one should only perform this action if A is close to unity. If $A<<1$, then it indicates that the DSCH is not constantly busy so a better solution to the problem is probably to lower the reserved power level, i.e. this would reduce the likelihood of code blocking events and help in fulfilment of equation (2).

If B equals zero, and L_{code} is greater than TH_{code} ($B=0$ and $L_{code}>TH_{code}$), then increase SF_{min} (max bit rate is decreased).

The reason herefore is that for cases where code limitation problems are absent some of the reserved channelization codes are preferably released by increasing SF_{min} with a factor of two. This helps to reduce the likelihood of code blocking for

DPCHs. However, it only makes sense to increase SF_{min} if there is a potential need for additional channelization codes. Hence, the action is only performed if $L_{code} > TH_{code}$, meaning if the code tree is already heavily loaded. Here TH_{code} is a

5　　threshold parameter and L_{code} is the current load of the code tree obtained from the resource manager (RM).

The effect of the criteria for reducing the reserved power level is illustrated in Fig. 4. The black curves correspond

10　　to the high reserved power level, while the blue curve corresponds to the reserved power level after the adjustment. The current example correspond to the case where $A=0.5$ and $P_{txDSCHest} = 0.5 P_{txDSCHreserved}$ prior to adjustment, and $X=3$ dB. For this particular case, as well as for other cases, the problem

15　　is obviously solved by reducing the power.

The HS-DSCH also benefits from adaptive algorithms for reservation of code resources as well as power levels. The algorithm specified in the present invention is equally

20　　applicable the HS-DSCH. Both for cases where the code resources for the HS-DSCH is changed dynamically in order to facilitate variable bit rates.

With regard to "territory method" for channelization code

25　　allocation: Once it has been decided to reserve a new root PDSCH code with a given SF, the next step is to decide where in the code tree this reservation is to be made. As an example, it is assumed that a code with SF=8 should be reserved. For that particular case there might actually be on

30　　the order of 1-6 availavable nodes (codes) in the tree. If one just randomly selects a node in the tree, one eventually reaches a situation where the code-tree becomes highly fracmented and difficult to manage as new users are being

admitted and dropped (due to ended calls).

In order to avoid such situations, a generic method is
proposed here where different strategies for code assignment
5   are used depending on the channel type (say DCH, DSCH, FACH,
etc). This method will be called "the territory method" in
the sequel.

The basic principle for the method is illustrated in Fig. 5,
10   where codes for DSCH (HS-DSCH) basically are assigned in the
tree starting from the left according to Fig. 5, or more
generally starting from a certain limb of the code tree.
Hence, codes assigned for DCH users should primarily be done
in the right part of the code tree according to the
15   illustration of Fig. 5, or more generally starting from
another limb, different from the certain limb, of the code
tree. In order to describe the method the following
definitions of code territories are introduced:

20   **Dedicated DSCH capacity**: In cases where a maximum SF for the
DSCH always should be reserved (i.e. guaranteed minimum bit
rate), part of the tree is reserved for DSCH and HS-DSCH. The
codes in this part of the tree cannot be used for other
users, say DCH.
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Default DSCH capacity: The default capacity is always
allocated to DSCH territory (to be used by HS-DSCH and DSCH)
when the total code tree load allows this. This is basically
what is expressed in above sections in particular relating to
30   adaptive adjustment of root spreading factor and DSCH power,
for the criteria for increase of SF_{min}. Here the SF is only
increased if the code tree is highly loaded.

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Additional DSCH capacity: When the default capacity is
allocated to the DSCH territory, additional code resources
might be needed if the DSCH is highly loaded. The upgrade to
a lower SF is done by including part of the codes in the
5   "additional DSCH territory" region, provided that free codes
are available. Once the traffic load on the DSCH start to
decline and and the criteria for increase of SFmin in the
above sections relating to adaptive adjustment of root
spreading factor and DSCH power is triggered, the additional
10   DSCH territory is downgraded.

The part of the code tree which is used by DSCH (HS-DSCH) is
called **DSCH_territory**. At the start this is set equal to the
default DSCH territory, whereafter the **DSCH-territory** is
15   dynamically updated, based on the load in the different parts
of the tree and the criterias listed in the above sections
related to adaptive adjustment of root spreading factor and
DSCH power.

20   The **dedicated DSCH capacity** can be used to always guarantee
some part of the tree for DSCH (HS-DSCH) users, so they get
some service even though the rest of the network for example
is occupied by real time users.

25   The **additional DSCH capacity** can be set to the whole tree,
but some part of the tree can be kept out of the additional
territory. Advantage of this is that when other users are
placed in this part, then they have not to be replaced, when
the DSCH territory is to be increased. For this increase it
30   may be necessary to reallocate the RT users in parts of the
tree, which belong to the additional territory.

Approximate parameter settings corresponding to best mode of

algorithm are: $TH_{A1}=0.5$, $TH_{A2}=0.9$, $TH_B=0.1$, and $TH_{Code}=0.8$.
These settings will result in an effective and robust
algorithm. However, depending on the actual system
configuration there might of course be room for optimization

5   of these parameter settings.

One of the preferred methods for operation of the DSCH is to
use LA. If LA is applied, adaptive allocation of code and
power resources are required in order to ensure effective

10   utilization of the DSCH.

The current working assumption within 3GPP is to operate the
HS-DSCH channel with constant power. A robust algorithm for
adaptive adjustment of the power level as well as reserved

15   code resources are therefore provided by the invention for
optimum management of the HS-DSCH.

Fig. 6 shows a schematic block diagram illustrating an
embodiment of the present invention. A shared channel

20   resource manager 1 (DSCH and/or HS-DSCH) receives several
inputs for evaluating and optimising or improving channel
resources and/or power. The shared channel resource manager 1
receives measurement results, i.e. data gained by periodical
measurement of code tree load, e.g. code blocking (B) and

25   code activity(A), as well as data gained by periodical
measurement of average shared channel transmit power.
Further, control parameters, preferably external algorithm
control parameters (e.g. thresholds TH_{A1}, TH_{A2}, etc), are
supplied to the channel resource manager 1.

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The channel resource manager 1 generates outputs for
controlling code reservation and power, e.g. reserved
channelization code(s) (root code for DSCH or number of codes

for HS-DSCH), and reserved power. The channel resource
manager 1 calculates the reservation of channelization
code(s) and power in accordance with the above explained
principles.

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The proposed algorithm runs on cell level.

The present invention for code reservation also applies to
the channel type HS-DSCH for the HSDPA concept, where the

10 number of codes with SF=16 is adaptively adjusted, i.e. SF is
constant.

The drawings are self-explanatory and represent full
disclosure of aspects of preferred embodiments of the

15 invention of their own value, even regarding those features
which are not explicitly described in the above description.

While the invention has been described with reference to
preferred embodiments, the description is illustrative of the

20 invention and is not to be construed as limiting the
invention. Various modifications and applications may occur
to those skilled in the art without departing from the scope
of the invention as e.g. defined by the appended claims.

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